The regression results reported in Tables VII.2.2 and VII.2.3 support hypothesis 2 insofar as they uncover a particular empirical regularity between non-cash purchases and spot market price: Average price in the region's spot market for cattle tends to be relatively low in weeks in which delivery of cattle from non-cash sources are relatively high, other things equal. The policy relevance of this empirical regularity depends, however, on the nature of the economic mechanism responsible for generating it. In section VIII.2, we propose and investigate one particular intuitive model of the scheduling of non-cash deliveries which could account for the empirical relationships we have found in the data.

VIII. WHAT ECONOMIC MECHANISMS COULD BE BEHIND THE EMPIRICAL RELATIONSHIPS?

VIII.1. Price Discovery and the Distribution of Spot Market Transaction Prices

To interpret the results of the empirical analysis of section VII.1, one must distinguish between "price discovery" and "price determination." Following Ward:

> "Price determination is the interaction of the broad forces of supply and demand which determine the market price *level*. ... Price discovery is the process of buyers and sellers arriving at a transaction price for a given quality and quantity of a product at a given time and place, ... and begins with the market price level. Because buyers and sellers discover prices on the basis of uncertain expectations, transaction prices fluctuate around that market price level."

Consistent with this view, the price of fed cattle in any one regional market at any given date is characterized, not by a single point value, but by a distribution of values. The general location of the distribution, represented by its mean value, is determined, in Ward's words, "by the broad forces of supply and demand." But transaction prices on individual lots of cattle can depart from the regional average price for a variety of reasons.

First of all, individual lots of cattle can be priced above or below the market average price because of better or worse than average lot quality. This, of course, was the motivation for including several lot quality indicators among the explanatory variables in section VII.1's price regression. And, as is discussed in Appendix C, the estimation results for the coefficients of these quality indicators are generally consistent with the common-sense expectations that higher-than-average quality lots are rewarded with a premium and lower-than-average quality lots suffer a discount, relative to the regional average price. That is, within a given distribution of transaction prices, prices for cattle of "low" quality tend to fall on the left-hand-side of the distribution while prices for cattle of "high" quality tend to fall on the right-hand-side of the distribution, other things equal.

Transaction prices may differ, however, even across lots of cattle of given quality. On any given market day, competitive conditions may vary within the regional market. A feedyard in one part of the region may be visited by only one bidder and, consequently, receive relatively "low" bids. For feedyards, in other parts of the region, competition among two or three bidders may be the norm for that day, and bids may be higher as a result.

A packer enters the spot market intending to procure cattle for slaughter for a given planning horizon. The volume of deliveries of cattle from non-cash sources that the packer will receive over that horizon is known in advance. As the graphical model of section VII.1 shows, a packer who enters the spot market expecting a relatively "large" volume of cattle from non-cash sources to be delivered during the planning horizon, will seek to supplement these pre-committed supplies with relatively "few" spot market purchases. As long as the packer possesses some degree of market power in the spot market (that is; as long as the packer faces a spot market "residual" supply curve that is upward sloping), buying fewer spot market cattle will mean paying lower spot market prices, on average. On the other hand, a packer who enters the spot market expecting relatively few deliveries from non-cash sources in the near-term future, will seek to make relatively "many" spot market purchases. To do so, more aggressive bidding will be needed and average transaction prices will be correspondingly higher.

Consequently, one would expect that packers who enter the spot market with a "high" value of section VII.1's "RRATIO" variable will, other things equal, wind up paying prices below the mean of the transaction price distribution. Packers who have a "low" value for RRATIO will tend to procure cattle at prices above the mean of the distribution. This is the phenomenon reflected in the statistically significantly negative values of section VII.1's estimates of the coefficient of RRATIO. As noted there, however, the magnitude of this effect appears to be relatively small.

It should be emphasized that the finding of a significantly negative estimate for the coefficient of RRATIO does not mean that an across-the-board decrease in the degree of reliance on non-cash purchases would raise the average level of prices received by feeders who sell on the spot market. RRATIO measures a packer's degree of reliance on non-cash supplies *relative to* its rivals' degree of reliance on non-cash supplies: An across-the-board change in the average level of non-cash purchases would leave RRATIO unaffected. Instead, the results of the analysis tell us whether a single plant's departure from the currently representative degree of reliance on non-cash purchases translates into a tendency to pay spot market prices that differ from average prices. Our conclusion is that plants anticipating near-term future non-cash cattle deliveries that are "high" (relative to its rivals' degrees of reliance on non-cash cattle) tend to pay spot market prices that are slightly below average. Plants anticipating near-term future non-cash cattle deliveries that are relatively "low" tend to pay spot market prices that are slightly above average.

VIII.2. Price Expectations and the Scheduling of Deliveries of Non-cash Cattle

The analysis of section VII.1 has implications about how the spot market prices paid by packers with different degrees of reliance on non-cash purchases tend to compare with the mean of the price distribution. The crucial issue from the perspective of feeders who sell on the spot market is whether heavy use of non-cash procurement methods leads to a reduction in the mean price, shifting the entire distribution. Indeed, the analysis of section VII.2 did uncover a negative correlation, in weekly time series data, between the weekly volume of regional non-cash deliveries and the week's average spot market price for the region. But the question remains, is this negative correlation evidence of a causal relationship between the use of non-cash procurement methods and cash prices? In the remainder of this section, we describe and conduct preliminary tests of a model of non-cash cattle delivery scheduling decisions. This model explains how week-to-week fluctuations in the regional average spot market price, even if caused by factors completely unrelated to the region's use of non-cash procurement methods, could, nonetheless, account for the empirical regularity of the type uncovered in section VII.2.

Marketing agreements normally give feeders the right to determine the number of cattle delivered in a given week but require that they notify packers of this number typically two weeks in advance of actual delivery. Thus, in week t (say), feeders determine QM_{t+2}, the number of marketing agreement cattle they will deliver to packers during week $t + 2$. One important determinant of this number, of course, is the number of cattle, owned by feeders with marketing agreements, that are expected to reach optimal slaughter weight and finish during week $t + 2$. QM_{t+2} can differ from the number of cattle "ready" for market, however, if the current and expected future prices of cattle are such that feeders have a profit incentive to ship cattle slightly short of market weight or to slightly delay shipment of finished cattle. Price discounts for underweight or over-fat cattle limit the feeders' ability to benefit by choosing a delivery week other than the week cattle will be ready. But the price discount penalties are not severe for deliveries one week before or one week after the week in which cattle are ready.

Under conventional pricing formulas, marketing agreement cattle delivered in a given week will bring a price based, in one way or another, on spot market prices paid for cattle the previous week. So cattle delivered in week $t + 2$ would bring a price based on p_{t+1}, the spot market price paid for (non-formula) cattle in week $t + 1$. Marketing agreement cattle delivered in week $t + 3$ (scheduled in week $t + 1$) would bring a formula price based on week $t + 2$ spot prices. So if feeders, in week t, expect the week $t + 2$ price to be high relative to the week $t + 1$ price, they might postpone, for one week, the delivery of some of the cattle ready for week $t + 2$ delivery, so that they could instead be delivered in week $t + 3$. On the other hand, if the week t expectation of week $t + 1$'s price is "high" relative to the expectation of week $t + 2$'s price, we would expect feeders to schedule large deliveries in week $t + 2$ in order to take advantage of the favorable formula prices that are anticipated for week $t + 2$. For notational convenience, we will use the symbol $E_t[p_s]$ to denote the expectation, formed in week t, of the spot market price in a subsequent week, week s. Then the argument above can be summarized in the following way: Other things equal, QM_{t+2} should be positively correlated with $E_t[p_{t+1}]$ and negatively correlated with $E_t[p_{t+2}]$.

Contracts for forward sales of cattle typically reserve delivery scheduling rights for the packer. As with marketing agreement cattle, however, some time is required to arrange transportation to the plant once the packer has made the decision to call a given number of cattle under forward contract in a given week. As we explained in Chapter V, the data support the assumption that the number of contract cattle to be delivered in a given week are typically determined either one or two weeks in advance. Moreover, by the time the packer has reached the point of deciding when to schedule deliveries, forward contract cattle represent a fixed-price cattle supply source.

Assume, for the moment, that the volumes of contract cattle deliveries are determined two weeks in advance. The typical lag between purchase and delivery of spot market cattle is approximately one week or so. From the packer's point of view, forward contract cattle deliveries in week $t + 2$ substitute for spot market purchases in week $t + 1$.[47] Thus if packers, in week t, expected a high realization for week $t + 1$'s spot price ($E_t[p_{t+1}]$ high), they would be inclined to schedule a large number of the fixed-price forward contract cattle for delivery in week $t + 2$. On the other hand, if packers, in week t, expect that the spot market price in week $t + 2$ will be high ($E_t[p_{t+2}]$ high), they would be inclined to hoard their limited inventory of fixed-price (forward contract) cattle, reserving them for delivery in week $t + 3$ when they can substitute for cattle that would otherwise have to be purchased on the spot market at a high price in week $t + 2$. Thus, just as with marketing agreement cattle deliveries, we would expect the number of forward contract cattle delivered in week $t + 2$, QC_{t+2}, to be positively correlated with $E_t[p_{t+1}]$ and negatively correlated with $E_t[p_{t+2}]$.

Two further details: First, for contract cattle, if the representative lag between scheduling and delivery is closer to one week than to two, a similar argument would establish that the volume of contract cattle delivered in week $t + 2$, say, should be positively correlated with p_{t+1} and negatively correlated with $E_{t+1}[p_{t+2}]$. Second, the forgoing argument; in the case of a two week lag between scheduling and delivery, for

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[47]We examined the distributions, for each plant in our sample, of the lag, in days, between purchase and delivery of spot market lots of fed cattle. For the

plants, respectively, the means (standard deviations) of these distributions were as follows:

example; might be interpreted to suggest that the key determinant of week *t* + *2* deliveries is the expectation of the *difference* between p_{t+2} and p_{t+1}, rather than the expectations of these two prices separately. This is a further hypothesis explored in our analysis.

We summarize our conjectures in the following two hypotheses:

Hypothesis 3A: The volume of marketing agreement cattle delivered in a given week; week *t* + *2*, say; tends, other things equal, to be positively correlated with the expectation, formed in week *t*, of the spot market price in week *t* + *1* and negatively correlated with the expectation; again, formed in week *t*; of the spot price in week *t* + *2*. The volume of forward contract cattle delivered in week *t* + *2* tends, other things equal, likewise to be positively correlated with $E_t[p_{t+1}]$ and negatively correlated with $E_t[p_{t+2}]$. Or, if the representative lag between scheduling and delivery of contract cattle is closer to one week than to two, the volume of contract cattle delivered in week *t* + *2* may tend, other things equal, to be positively correlated with p_{t+1} and negatively correlated with $E_{t+1}[p_{t+2}]$.

Hypothesis 3B: The volume of marketing agreement cattle delivered in a given week; week *t* + *2*, say; tends, other things equal, to be negatively correlated with $E_t[p_{t+2} - p_{t+1}]$. The volume of forward contract cattle delivered in week *t* + *2* tends, other things equal, likewise to be negatively correlated with $E_t[p_{t+2} - p_{t+1}]$. Or, if the representative lag between scheduling and delivery of contract cattle is closer to one week than to two, the volume of contract cattle delivered in week *t* + *2* may tend, other things equal, to be negatively correlated with $E_{t+1}[p_{t+2}] - p_{t+1}$.

To this point, our argument establishing a connection between price expectations and marketing agreement and contract delivery volumes is incomplete because it takes account only of the intertemporal arbitrage opportunities (the opportunities to achieve an incremental increase in net revenue by rescheduling delivery from one week to another) available to the decision makers who schedule the delivery of cattle procured by non-cash means, but ignores the arbitrage opportunities available to spot market sellers of cattle. It is important to consider these as well, especially in view of the fact that, for the four Texas plants over the period of investigation, the spot market was a considerably larger source of fed cattle than were non-cash procurement methods.[48]

Consider a spot market seller with cattle "ready" for market in week *t*. Selling the cattle "now" would bring the current spot market price, p_t, while deferring sale for one week would return an expected price of $E_t[p_{t+1}]$. If $E_t[p_{t+1}]$ were sufficiently larger than p_t, the spot market seller might, in fact, have an incentive to defer sale. This strategy would not be costless, however. The cattle would have to be fed for another week, the receipt of sales revenues would be postponed for another week, and, if the cattle were currently at optimal market weight and finish, they might suffer a slight price discount if their sale were postponed for a week. The magnitude of these arbitrage costs is affected by several factors. Some factors, like current feed prices and interest rates, are relatively "generic" in that they affect the arbitrage costs of all lots of cattle more-or-less equally. Other factors, like the current condition of the cattle and the availability of pen space at the feedyard where the cattle are fed, are "lot-specific" in that they affect arbitrage costs on a lot-by-lot basis. At any given point in time, therefore, the lots of cattle earmarked for spot market sale are characterized by a distribution of arbitrage costs.

Now assume that, in week *t*, an intertemporal arbitrage opportunity were to emerge, at least temporarily: $E_t[p_{t+1}] > p_t$, say. Spot market sellers would respond, starting with the lots that can be arbitraged at lowest cost, by withholding these lots from week *t's* spot market and deferring their sale for one week. This intertemporal reallocation will have the effect of driving p_t higher and driving $E_t[p_{t+1}]$ lower. As lots characterized by increasingly higher arbitrage costs were reallocated, p_t and $E_t[p_{t+1}]$ would move closer together until the profitable opportunities for intertemporal arbitrage were exhausted. At this point, the surviving gap between the current spot market price and the current expectation of next week's spot market price would be equal to the smallest arbitrage cost among the lots of cattle remaining among those supplied to the week *t* market.

A similar response would obtain if expected next week's price were sufficiently smaller than current price: $E_t[p_{t+1}] < p_t$, at least temporarily. In this case, starting with the lots subject to the smallest arbitrage cost, spot market cattle originally earmarked for sale in week *t + 1* would be intertemporally reallocated forward to week *t*, tending to drive p_t down and to drive $E_t[p_{t+1}]$ up. The arbitrage cost of this marketing strategy would typically result from the price discount suffered as a result of selling cattle short

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[48]Over the sample period, for the four plants combined, spot market purchases accounted for 71.29% of fed cattle slaughter. As the figures in Table V.2 imply, the plant-by-plant percentages of fed cattle slaughter attributable to spot market purchases were

of optimal market weight and finish. In the end, $E_t[p_{t+1}]$ and p_t would again be driven toward convergence up to marginal arbitrage cost.

The point is that, if we assume that emergent opportunities for intertemporal arbitrage are always fully exploited and, with their exploitation, they are ultimately eliminated, we can think of the surviving gap between this week's price and this week's expectation of next week's price as a reflection of marginal arbitrage cost, not only within the population of spot market lots, but within the population of lots earmarked for sale under marketing agreements or forward contracts as well. But, because spot market sales represent the predominant component of fed cattle marketings in the Texas Panhandle (accounting for over 70% of fed cattle slaughter by the four plants over the period of investigation) the shape and location of the distribution of arbitrage costs within the population of spot market lots will be the primary determinant of the gap between p_t and $E_t[p_{t+1}]$.

If the only factors affecting the arbitrage costs of lots of cattle were generic in nature, tending to affect arbitrage costs for all lots equally, the correlations described in Hypotheses 3A and 3B would not necessarily obtain. A "large" gap between the previous week's spot market price and a previously formed expectation of this week's spot price would mean that arbitrage costs for spot market cattle "ready" for sale tend to be "high." With only generic factors affecting arbitrage costs, this would mean correspondingly "high" arbitrage costs, on average, for marketing agreement cattle and forward contract cattle, leaving few profitable arbitrage opportunities available to the decision makers who schedule delivery of cattle from these sources. Since the arbitrage cost of a lot of cattle is also affected by lot-specific factors, however, the distributions of arbitrage costs for spot market cattle, marketing agreement cattle, and forward contract cattle do not move in lockstep. A "large" gap between the previous week's price and a previously formed expectation of this week's price, a reflection of generally high arbitrage costs within the population of spot market cattle "ready" for sale, will, in general, mean a "large" number of profitable arbitrage opportunities for the decision makers who schedule delivery of marketing agreement and forward contract cattle. Hypotheses 3A's and 3B's conjectured correlations between delivery volumes and actual and expected prices should be present in the data.

The "other things equal" qualifications in Hypotheses 3A and 3B are reminders that many other factors influence feeders' and packers' decisions about the number of non-cash cattle to deliver in a given week. For example, feeders' weekly marketing agreement delivery numbers will be heavily influenced by the number of cattle reaching optimal market potential each week. The amount of available pen space in the feedyard will also be a factor: When space is tight, feeders may be inclined to free up pen space by shipping marketing agreement cattle slightly short of optimal market finish, especially if there is an opportunity to purchase feeder cattle at a relatively low price. From a particular packer's point of view, the number of contract cattle to call in a given week depends, in large part, on the current inventory of contract cattle; that is, the total volume of cattle under contract for delivery at some time during the current month.

These packer- and feeder-idiosyncratic factors are important in delivery scheduling decisions, but are not reflected in our data set and, for the most part, can be proxied only highly imperfectly. So we will omit them from the regression analysis used to investigate the relationship between marketing agreement and contract deliveries and expected spot market prices.

The analysis will focus on the following regression equations:

$$QM_{t+2} = \delta_0 + \delta_1 E_t[p_{t+2}] + \delta_2 E_t[p_{t+1}] + \varepsilon_{t+2} \tag{4a}$$

$$QM_{t+2} = \gamma_0 + \gamma_1 E_t[p_{t+2} - p_{t+1}] + \eta_{t+2} \tag{4b}$$

$$QC_{t+2} = \delta_0 + \delta_1 E_t[p_{t+2}] + \delta_2 E_t[p_{t+1}] + \varepsilon_{t+2} \tag{5a}$$

$$QC_{t+2} = \gamma_0 + \gamma_1 E_t[p_{t+2} - p_{t+1}] + \eta_{t+2} \tag{5b}$$

$$QC_{t+2} = \delta_0 + \delta_1 E_{t+1}[p_{t+2}] + \delta_2 p_{t+1} + \varepsilon_{t+2} \tag{6a}$$

$$QC_{t+2} = \gamma_0 + \gamma_1 (E_{t+1}[p_{t+2}] - p_{t+1}) + \eta_{t+2} \tag{6b}$$

where QM_{t+2} (QC_{t+2}) is the number of head of marketing agreement (forward contract) cattle delivered (either to a given plant or to the four plants combined) in week $t + 2$. p_t represents week t's average spot market price of steers in the Oklahoma-Texas panhandle region. $E_s[p_r]$, for various values of s and r, denotes the expectation, formed in week s, of week r's value of price. More will be said about these expectations in a moment. ε_{t+2} and η_{t+2} represent the effects of omitted variables that may influence non-cash cattle delivery volumes in week $t + 2$. With respect to the scheduling of marketing agreement deliveries, hypothesis 3A implies a negative value for δ_1 and a positive value for δ_2 in equation (4a). If, as hypothesis 3B suggests, the appropriate indicator of intertemporal arbitrage opportunities is the expected price *difference*, then one would expect a negative value for γ_1 in equation (4b). Because there is some ambiguity about the representative lag between scheduling and delivery in the case of forward contract cattle, we posit two sets of relations for QC_{t+2}. One, consisting of equations (5a) and (5b), pertains to a two week lag; the other, consisting of equations (6a) and (6b), is relevant to a one week lag. As in the case of marketing agreement cattle, hypothesis 3A implies a negative value for δ_1 and a positive value for δ_2 in equations (5a) and (6a). Hypothesis 3B implies a negative value for γ_1 in equations (5b) and (6b).

To carry out estimation of equations (4a), (4b), (5a), (5b), (6a), and (6b) we must first address the question of how decision makers will form their two-week-ahead ($E_t[p_{t+2}]$) and one-week-ahead ($E_t[p_{t+1}]$ or $E_{t+1}[p_{t+2}]$) forecasts of price and their two-week-ahead forecasts of the change in price ($E_t[p_{t+2} - p_{t+1}]$). One conventional modeling approach is to assume that the forecasts will be based on the information contained in a time series regression of the actual values of the variable to be forecast on a set of variables whose values are thought to be relevant to the determination of the forecast variable and were observable to decision makers in the week in which the forecast was formed. The series of fitted values from such regressions can be thought of as forecasts of price based on the information contained in the forecasting equation's explanatory variables. In the spirit of that conventional approach, we posit the following forecasting equations:

One-week-ahead price forecasting equation:

$$\begin{aligned} p_{t+1} = a_0 &+ a_1\, p_t + a_2\, p_{t-1} + a_3\, \Delta fp_t + a_4\, val_t + a_5\, r_t \\ &+ a_6\, cf_t + a_7\, fcp_t + a_8\, crnp_t \\ &+ a_9\, cpl_t + a_{10} lcpl_t + \mu_{t+1} \end{aligned} \tag{7}$$

Two-week-ahead price forecasting equation:

$$\begin{aligned} p_{t+2} = b_0 &+ b_1\, p_t + b_2\, p_{t-1} + b_3\, \Delta fp_t + b_4\, val_t + b_5\, r_t \\ &b_6\, cf_t + b_7\, fcp_t + b_8\, crnp_t \\ &+ b_9\, cpl_t + b_{10} lcpl_t + \mu_{t+2} \end{aligned} \tag{8}$$

Two-week-ahead price difference forecasting equation:

$$\begin{aligned} p_{t+2} - p_{t+1} = c_0 &+ c_1\, p_t + c_2\, p_{t-1} + c_3\, \Delta fp_t + c_4\, val_t + c_5\, r_t \\ &+ c_6\, cf_t + c_7\, fcp_t + c_8\, crnp_t \\ &+ c_9\, cpl_t + c_{10}\, lcpl_t + \mu_{t+2} \end{aligned} \tag{9}$$

where; for s = t - 1, t, t + 1, and t + 2; p_s is the region's average steer price in week *s*. Δfp_t is the change in the price of week *t*'s "nearby" Chicago Mercantile Exchange live cattle futures contract from the first reporting day of week *t - 1* to the first reporting day of week *t*. The "nearby contract" for week *t* is defined as the one associated with the first contract month to follow week *t*, assuming that the first day of the contract month is at least 7 days later than the first reporting day of week *t*. If the first day of a contract month is fewer than 7 days later, the next contract is taken as the "nearby contract." val_t is the average box beef cutout value for week *t*.[49] r_t is the 6-month Treasury bill rate

[49]This is exactly the same as the AVGVAL series defined and used in section VII.2.

on the Friday immediately prior to week *t*.[50] cf_t is the number of cattle (in thousands of head) on feed in week *t* in Texas feedyards with capacity of 1000 head or more. fcp_t is the price of feeder cattle (Oklahoma City; steers: medium #1, 600-650 lbs.) in week *t* in \$/cwt. $crnp_t$ is the price of feed corn (central Illinois; #2, yellow) in week *t* in \$/bu. cpl_t is the number of cattle (in thousands of head) placed on feed during week *t* in Texas feedyards with capacity of 1000 head or more. $lcpl_t$ is a simple average of the values of cpl_s for *s* values corresponding to weeks 15, 16, 17, and 18 weeks prior to week *t*. This variable is intended to provide a rough indication of the number of cattle that may be reaching market weight in feedyards serving the four Texas plants.[51] The μ_t terms in equations (7), (8), and (9) represent random errors.

Equations (7), (8), and (9) were first estimated by ordinary least squares (OLS) using 65, 64, and 64 weekly observations, respectively.[52] Each equation was tested for the presence of serial correlation in the error term (correlation between μ_t and μ_s for $t \neq s$). The hypothesis of no serial correlation in the errors could not be rejected in the case of equations (7) and (9), but was rejected at the 5% significance level in the case

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[50]The 6-month Treasury bill rate is included as a convenient proxy for the interest rates packers or feeders might face in the capital markets in which they secure financing for their operations. While the Treasury bill rate may not accurately reflect the *level* of the relevant capital market rates, the changes in the two rates are undoubtedly highly correlated.

[51]We could find only monthly (not weekly) data for the variables cf_t, fcp_t, $crnp_t$, cpl_t, and $lcpl_t$. In these cases, weekly estimates were constructed from monthly data using the following conventions. cf_t: The reported number of cattle on feed for the first day of a month was assigned to the week containing the month's first day. Linear interpolation was used to estimate cattle on feed during other weeks. fcp_t and $crnp_t$: Prices reported for the month were assigned to the week containing the 15th day of the month. Linear interpolation was used to estimate prices for other weeks. cpl_t and $lcpl_t$: Weekly cattle placements were estimated based on the assumption that the number of placements for a given month was uniformly distributed across days of the month.

[52]The data set contains essentially complete records on the lots of cattle killed by the four Texas plants during a 67 week time span from the week of February 5, 1995 through the week of May 12, 1996. Because estimation of equations (7), (8), and (9) required lagged values, fewer than 67 observations were usable. Because equations (8) and (9) required one more lagged value of p_t than equation (7), the number of usable observations was one fewer in equations (8) and (9) than in equation (7).

of equation (8).[53] Ordinary least squares regression results for equations (7) and (9) are reported in Tables VIII.2.1 and VIII.2.2 respectively. In the analysis of equations (4a), (4b), (5a), (5b), (6a), and (6b), $E_t[p_{t+1}]$ was taken to be the series of fitted values from OLS estimation of equation (7). Shifting the values in this series forward one time period gives us our proxy for $E_{t+1}[p_{t+2}]$. $E_t[p_{t+2} - p_{t+1}]$ was taken to be the series of fitted values from OLS estimation of equation (9).

Evidence of serial correlation in the errors of equation (8) requires that this equation be estimated by a procedure other than OLS. The correction for serial correlation is complicated, somewhat, by the presence of lagged dependent variables (p_t and p_{t-1}) among the regressors. We use a feasible generalized least squares procedure suggested by Hatanaka.[54] In the first stage, p_t and p_{t-1} are regressed on a set of instrumental variables which, in our application, were taken to be the remaining explanatory variables in equation (8) plus an additional lag of each. In the second stage, a version of equation (8) was estimated by OLS, but with the fitted values from the first stage regressions, $\hat{p}_t$ and $\hat{p}_{t-1}$, replacing p_t and p_{t-1}. The residuals from this regression, denoted $\tilde{\mu}_{t+2}$, were recovered.[55] An autoregressive model with six lags (in our case) was estimated to obtain consistent estimates of the parameters of the μ_t process. In this regression, only the estimate of the second-order autoregressive parameter, $\tilde{\rho}_2$, was significantly different from zero at conventional levels.[56]

Using $\tilde{\rho}_2$, the consistent estimate of the second-order autoregressive parameter from the μ_{t+2} process, the data for equation (8) were filtered as follows:

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[53]Testing for serial correlation in the errors of these equations is complicated by the presence of lagged dependent variables (p_t and p_{t-1}) among the regressors. We used a testing procedure, suggested by Greene (section 13.5.3), that is a modification of the Breusch-Godfrey test. It involves regressing the residuals from OLS estimation on the original equation's explanatory variables and six (in our application) lags of the residuals. A standard F-test of the null hypothesis that the coefficients of the lagged residuals are all zero amounts to a test of no serial correlation (up to order six). The calculated F-statistics for equations (7), (8), and (9) were 0.707, 3.849, and 1.553, respectively. Compared to a 5% critical value of approximately 2.3, the results led to rejection of the null hypothesis (no serial correlation) in the case of equation (8) and failure to reject for equations (7) and (9).

[54]See Greene, section 13.7.2.

[55]In forming the residuals, the actual values of p_t and p_{t-1} were used instead of the fitted values from the first stage regressions.

[56] $\tilde{\rho}_2$ was significantly different from zero at the 3% level. None of the other autoregressive parameters were significantly different from zero at the 15% level.

$$p_{t+2}^* = p_{t+2} - \tilde{\rho}_2\, p_t,$$
$$p_t^* = p_t - \tilde{\rho}_2\, p_{t-2},$$
$$\Delta fp_t^* = \Delta fp_t - \tilde{\rho}_2\, \Delta fp_{t-2}, \ldots \text{ etc.}$$

In the final stage of the Hatanaka procedure, p_{t+2}^* is regressed on the "starred" versions of equation (8)'s explanatory variables and on $\tilde{\mu}_t$, the twice-lagged residual from the second stage regression. The resulting estimates of the regression parameters, $\hat{b}_0$, $\hat{b}_1$, $\hat{b}_2$, . . ., etc., are consistent estimates of the parameters of equation (8). An updated estimate of the second-order autoregression parameter, $\hat{\rho}_2$, is formed by adding the estimate of the coefficient of $\tilde{\mu}_t$ to $\tilde{\rho}_2$. Table VIII.2.3 reports these estimates.

Developing consistent forecasts based on a model with serially correlated errors requires that information contained in lagged residuals be taken into account in forming the forecast. For the two-week-ahead forecast of price required for the analysis of equations (4a), (4b), (5a), (5b), (6a), and (6b) we take

$$E_t[p_{t+2}] = \hat{b}_0 + \hat{b}_1\, p_t + \ldots + \hat{b}_{10}\, lcpl_t + \hat{\rho}_2\, \hat{\mu}_t.$$

Notice that all of the terms on the right-hand-side, including $\hat{\mu}_t$, are in the week *t* information set, as required.[57]

Having used forecasting equations (7), (8), and (9) to develop proxies for the expectations, equations (4a), (4b), (5a), (5b), (6a), and (6b) were estimated by ordinary least squares using 62 week of data.[58] Results are reported in Tables VIII.2.4, VIII.2.5, VIII.2.6, and VIII.2.7. The t-statistics reported in those tables are based on

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[57]In forming these forecasts, we take $\hat{\mu}_t$ to be the residual from equation (8) based on the parameter estimates obtained in the final stage of the Hatanaka procedure, not the $\tilde{\mu}_t$ residual obtained in an earlier stage. The squared simple correlation coefficient between the two-week-ahead forecast series formed in this manner and the actual price series was 0.7502.

[58]The requirement of additional lagged values in the Hatanaka method used to estimate equation (8) led to the loss of additional observations.

heteroscedasticity and autocorrelation consistent standard errors calculated using the Newey-West procedure.[59]

Hypothesis 3A, as it applies to marketing agreement cattle, implies a negative value for δ_1 and a positive value for δ_2 in equation (4a). The estimation results for equation (4a), reported in Table VIII.2.4, show that, in all cases (for each of the four plants separately, and for the four plants combined) the signs of the point estimates of δ_1 and δ_2 are consistent with the hypothesis. Moreover, in all cases except the coefficient estimates are significantly different from zero (in a one-tailed test) at the 1% level.

When we test hypothesis 3A as it applies to forward contract cattle, we are limited to just two cases: forward contract deliveries to , and to the four plants combined. Deliveries of contract cattle to plants were sufficiently infrequent as to leave, in each of those cases, a significant number of weeks of the sample with zero total delivery volume.[60] Moreover, in the case of forward contract cattle, the implications of hypothesis 3A are not as sharp as they are for marketing agreement cattle because of the ambiguity with respect to the length of the representative interval between the scheduling of contract cattle and their delivery: two weeks or one week. If two weeks is the appropriate interval, the argument supporting hypothesis 3A implies that δ_1 should be negative and δ_2 should be positive in equation (5a). If one week is more typical, we should find the same sign pattern in equation (6a).

Results of estimation of equations (5a) and (6a) are reported in Table VIII.2.6. Once again, the signs of the point estimates of the coefficients of price expectations are consistent with the hypothesis in all cases, although statistical significance is generally lacking. The results are stronger for the four-plant-combined regression than for the

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[59]See Greene, section 13.4.3. The Newey-West procedure produces consistent estimates of OLS standard errors that are robust with respect to heteroscedasticity and autocorrelation of unspecified form.

[60]The 62-week sample proportions of zero observations for the QC_{t+2} series were An entirely defensible method of estimating equations (5a), (5b), (6a), or (6b) for any one of the plants individually would require the use of a limited dependent variable procedure such as Tobit. See Greene, section 20.3.2. That kind of exercise was not undertaken here because of the difficulties of generating heteroscedasticity and autocorrelation robust standard errors (*a la* Newey and West) in the context of Tobit estimation.

regression, particularly in the case of equation (6a).[61] For that case, the estimate of δ_1 is significantly negative at the 10% level and the estimate of δ_2 is significantly positive at the 5% level.

Hypothesis 3B addresses the possibility that the key determinant of week $t + 2$ deliveries may be an expectation of a price change, rather than the expectations of the two prices separately. As it applies to marketing agreement cattle, hypothesis 3B can be tested within the context of regression equation (4b). Estimation results are reported in Table VIII.2.5. There is limited support for hypothesis 3B, which implies that γ_1, the coefficient of $E_t[p_{t+2} - p_{t+1}]$, should be negative. In all but one case the estimated value of γ_1 is negative, but significance is generally lacking. The estimates are significantly negative in regression (at the 5% level) and in the four-plant-combined regression (at the 10% level). When applied to forward contract cattle deliveries, hypothesis 3B receives stronger support, as is evident in the regression results presented in Table VIII.2.7. For the four-plant-combined case, the estimates of γ_1 are significantly negative at the 5% level in both equation (5b), which assumes a two week representative interval between scheduling and delivery, and equation (6b), which is based on the assumption of a one week interval.

To summarize, in the case of marketing agreement cattle, the largest non-cash supply source of cattle for the four Texas plants during the period of investigation, hypothesis 3A finds strong support in three of the four individual plant-level analyses and in the four-plant-combined analysis. Hypothesis 3B, on the other hand, receives, at best, only limited support. In our judgment, these findings are strongly supportive of the general notion that marketing agreement feeders' delivery scheduling decisions are related to their expectations of future spot market prices in the manner in which we have suggested. We also offered the further conjecture that the delivery scheduling decision rule may, in fact, rely on the summary measure of future market conditions given by the expected *change* in price between next week and the week after next, rather than on the expected *levels* of these two prices separately. There is only minimal support for this additional conjecture.[62]

In the case of forward contract cattle, tests of hypotheses 3A and 3B are complicated by the ambiguity about the length of the typical interval between delivery

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[61]Keep in mind that the results of estimation of the versions of equations (5a), (5b), (6a), and (6b), should, perhaps, be discounted to a degree because of our failure to properly account for the limited dependent variable problem.

[62]So, in fact, an expected spot price change of \$0.20/cwt, say, may have a different influence on feeders plans for delivery under marketing agreements depending on the current level of spot price.

scheduling and delivery.[63] Nevertheless, for the forward contract cattle case, hypothesis 3A finds weak support in the results of estimation of the four-plant-combined version of equation (6a) (which assumes a one week interval between scheduling and delivery). Hypothesis 3B finds moderate support in the four-plant-combined regressions based on equations (5b) (assuming a 2 week interval) and (6b) (assuming a one week interval).

As mentioned earlier, several important feeder- and packer-specific factors affecting the scheduling of marketing agreement and forward contract deliveries were omitted from the regression models of equations (4a), (4b), (5a), (5b), (6a), and (6b) because data were unavailable. This undoubtedly accounts for the fact that the overall explanatory power of these regressions is quite low, as is evidenced by the R^2 values that are reported in Tables VIII.2.4, VIII.2.5, VIII.2.6, and VIII.2.7. Nonetheless, we interpret the results of the regression analysis as providing support for the intuitive model of non-cash supply delivery scheduling that underlies hypotheses 3A and 3B:[64] Other things equal, weekly marketing agreement and forward contract deliveries tend to be positively correlated with a previously-formed expectation of last week's price and negatively correlated with a previously-formed expectation of this week's price.

Packers and feeders make week-to-week decisions about the scheduling of forward contract and marketing agreement cattle deliveries. To a large extent, these decisions are driven by a desire to slaughter cattle when their optimum biological potential is reached. But there is some capability for intertemporal shifting of deliveries in response to economic considerations dictated by changing spot market prices. In particular, we have argued that the incentives confronting feeders and packers will lead, other things equal, to "high" deliveries of marketing agreement and forward contract cattle in weeks in which the *ex ante* expectation of the spot market price is "low."[65] But because the experienced market participants who make the scheduling decisions are undoubtedly quite good forecasters of price (at least over a relatively short forecast horizon, such as one or two weeks), their *ex ante* expectations are likely to be quite highly correlated with the *ex post* realizations of price. So the tendency for weekly deliveries from non-cash supply sources to be negatively correlated with the

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[63]Tests of hypotheses 3A and 3B are further complicated by the limited dependent variable problem that plagues each of the plant-level analyses, but especially in the cases of . See the discussion in footnote 60.

[64]This support is strong in the case of the quantitatively most significant non-cash supply source: marketing agreement cattle. But there is also some limited support for the model in the case of forward contract cattle.

[65]The regression analysis of this section has uncovered some empirical regularities in the data that are consistent with this conjecture.

unobserved *ex ante* price expectations could well manifest itself in a negative correlation between weekly non-cash deliveries and the observed *ex post* realizations of price. This, of course, is exactly the kind of empirical relationship between delivery volumes for non-cash cattle and spot market cattle prices revealed by the analysis of section VII.2.

This line of reasoning counsels caution in the interpretation of the empirical findings of section VII.2. As those findings demonstrate, the data reveal a tendency for spot market cattle prices to be "low," other things equal, in weeks in which deliveries of cattle procured by non-cash means are "high." But this empirical regularity does not necessarily mean that there is an underlying mechanism whereby large deliveries of non-cash cattle in a particular week *cause* that week's spot market price to fall. Even if week-to-week fluctuations in the spot cattle price in a regional market were generated essentially independently of the region's deliveries of non-cash cattle,[66] the incentives that influence the delivery scheduling decisions of feeders and packers would still result in a negative correlation between observed spot price and slaughter of cattle procured by non-cash methods in weekly time series data.

Our point is that an observed negative correlation between non-cash cattle deliveries and spot market prices is not necessarily evidence of abusive market conduct on the part of packers who utilize non-cash procurement methods. We have argued this point with what might be called a *partial* analysis rather than an *equilibrium* analysis insofar as we have specifically addressed only the effect that intertemporal fluctuations in the spot market price would have on packers' and feeders' non-cash cattle delivery scheduling decisions; but not how or whether those delivery scheduling decisions would feed-back into spot market price determination. This partial approach was motivated by the observation that the spot market remains the dominant source of fed cattle, accounting for about 71% of fed cattle slaughter in the GIPSA data. The largest non-cash source, marketing agreements, is responsible for 21% of fed cattle slaughter. Our simplified, "partial," approach is implicitly based on the assumption that spot market transaction volume and price are jointly determined in each period; the resulting price (or, rather, the expectations thereof), in turn, influence non-cash delivery schedules; which then have only negligible feedback into spot market price determination.

Providing a complete, coherent equilibrium analysis is beyond the scope of this report, but we can offer a preliminary sketch of the ideas such a model would incorporate. Packers' and feeders' non-cash cattle delivery scheduling decisions tend to have a mirror image in packers' decisions about how many spot market cattle to purchase in a given week For example, if in week t, $E_t[p_{t+1}]$ is "high" and $E_t[p_{t+2}]$ is "low," the incentives we have described will lead to "high" deliveries of both marketing agreement and forward contract cattle in week t + 2. With a relatively large supply

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[66]For example, one can imagine a hypothetical possibility in which regional market spot prices are determined primarily by broader, national market factors.

precommitted for week $t + 2$, packers will desire to purchase "few" spot market cattle in week $t + 1$ (for delivery in week $t + 2$), with this easing of demand having the tendency to reduce the spot market price in week $t + 1$. Thus, it would appear that the intertemporal shifting of non-cash cattle deliveries, and the accommodating intertemporal pattern of spot market demand, might simply serve to attenuate cycles in the spot market price: When a confluence of exogenous factors leads to week t expectations of a "high" price in week $t + 1$, non-cash cattle deliveries will substitute, to some extent, for spot cattle purchases and the anticipated peak in spot prices will turn out to be rather lower than if these substitution possibilities had not been available. (As we have noted in the text of the report, the actions of spot market sellers to exploit the intertemporal arbitrage opportunities available to them also work to "smooth-out" price cycles.) While this is merely a preliminary sketch of how our informal model might be extended to allow for feedback from non-cash cattle delivery scheduling decisions to spot market price determination, it does not appear that the extension would alter our findings appreciably.

IX. DOES THE FORMULA BASE PRICE INFLUENCE SPOT MARKET PRICING CONDUCT?

What we have accomplished up to this point is to demonstrate that the data exhibit a negative relationship between the delivery volumes of cattle procured by non-cash methods and spot cattle prices, but that this negative relationship does not necessarily mean that higher levels of non-cash cattle usage will cause lower spot market cattle prices. By the same token, the negative relationship is not necessarily evidence of "abusive" conduct by packers. To investigate the possibility of abusive or "manipulative" behavior by packers, one must carefully examine the market's institutional arrangements for situations in which the packer would have the opportunity and incentive to engage in such behavior. One conjecture, sometimes put forward by producers, is that packers' spot market pricing conduct is used to manipulate their marketing agreement pricing formula base to their advantage. That is the conjecture examined in this section.

For the four Texas plants during the period of investigation, all cattle delivered under marketing agreements were priced by formulas. The use of formulas, moreover, was reserved almost exclusively for marketing agreement cattle.[67] Generally speaking, formulas involve a base price, that applies to cattle of given quality characteristics (typically defined in terms of a given yield grade, quality grade, and carcass weight

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[67] purchased 13 lots of forward contract cattle on a formula basis. All other lots of spot market and forward contract cattle, for all plants, were priced on a non-formula carcass or live weight basis.